I. C. 6725 JUNE, 1933

DEPARTMENT OF COMMERCE
UNITED STATES BUREAU OF MINES
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EXPLOSIVES ACCIDENTS IN CALIFORNIA METAL MINES

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DEPARTMENT OF COMMERCE --- BUREAU OF MINES

EXPLOSIVES ACCIDENTS IN CALIFORNIA METAL MINES[1]

By S. H. Ash[2]

On December 2, 1932, the Governor of California called upon the representatives of the mining industry of the State to attend a meeting at Sacramento to discuss ways and means of assisting in relieving some of its perplexing and extremely distressing problems, particularly the mounting cost of accidents which faces the industry with an industrial insurance rate for classification of $11.85 per $100 of pay roll, effective January 1, 1933. The significance of this fact is at once apparent when it is realized that the classification rates per $100 of pay roll for mining have steadily increased for some time, as follows: $5.81 in 1924, $6.54 in 1925 and 1926, $8.04 in 1927, $8.53 in 1928, $9.05 in 1929, $9.42 in 1930, $10.54 in 1931, $10.99 in 1932, and $11.85 in 1933. In other words, the cost rates have more than doubled, while statistics indicate that the accident rates have shown an entirely different trend.

At the meeting mentioned, one of the management officials sounded an effective keynote when he declared that a spade should be called a spade. The perplexing problems of any industry can be approached best and remedies applied if that policy is kept to the front. It is appropriate to mention that high accident rates and a decrease in wages in recent years have unquestionably accounted in part for a high unit cost rate on a pay-roll basis; it also is well to explain that the policy years[3] 1926 to 1930, inclusive, are the years on which the accident-cost experience for 1933 is based. That accident rates have not undergone the expected beneficial change in California's experience is apparent in the words of a Bureau of Mines report:[4]

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1 The Bureau of Mines will welcome reprinting of this article, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6725."

2 District engineer, safety division, U. S. Bureau of Mines, Berkeley, Calif.

3 A policy year includes all of the policies written during the designated year but refers to experience developed in the following calendar year.

4 U. S. Bureau of Mines, Accident-Prevention Record of the Mining Industry in California in 1931: Health and Safety Survey, Demographical Division, Oct. 26, 1932.

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The safety record for mines in California in 1931 was better than that for 1930 and for most years during the past decade, according to figures just compiled by the United States Bureau of Mines from reports received from operating companies through the Industrial Accident Commission of California. Records for the State indicated an average rate of 109 accidents per million man-hours of employment as compared with 120 in the previous year. On only three occasions since 1921 has the accident rate for California mines been more favorable than it was last year, these instances being in 1927, 1928, and 1929.

The figures prepared by the Bureau of Mines for 1931, which covered all important mines and numerous small operations, showed a total of 640 mines employing 5,553 men who worked a total of 10,755,493 man-hours; this was 10 percent below the number of hours worked in 1930. Each employee worked an average of 241 days or 1,940 hours. The average working time in the preceding year was 251 days or 2,014 hours per employee. Accidents caused 15 deaths and 1,160 nonfatal injuries.

According to the Industrial Accident Commission's classification, 19 men were killed during 1931. Of these deaths, three, or 15.78 percent, were caused by explosives--a slightly higher rate for explosives than in 1930.

The following list (table 1) of fatal accidents in the California mining industry in 1932 were reported to the Industrial Accident Commission:

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Table 1.- Fatal accidents in mining in California during 1932

Date of accident	Kind of mine	Number employed	Number killed	Cause of accident
Jan. 28	Gold mine.	Over 50	2	Explosives (fuse and detonator blasting). Picked into missed shot in winze.
Feb. 13	do.	Over 100	3	Explosives (fuse and detonator blasting). Stayed too long. Wet fuse. In drift.
Mar. 23	do.	Less than 10	1	Caught in machinery on surface.
Mar. 30	Gold dredge.	Over 20	1	Fell from dredge; drowned; on surface.
Apr. 12	Gold mine.	Less than 10	1	Fell down shaft.
Apr. 12	do.	do. 20	1	Electrocuted. Signal wire charged (in winze) with 440 volts.
May 16	do.	Over 100	1	Struck by falling timber. Underground.
May 27	do.	do.	1	Fall of rock. Underground.
July 6	Gold dredge.	Over 20	1	Electrocuted on dredge.
July 30	Gold mine.	Less than 10	1	Explosives (fuse and detonator blasting) 7 holes. Carbide lamp extinguished. Stayed too long in winze.
Aug. 24	do.	3	1	Explosives (fuse and detonators) in drift. Primer exploded, container fell, transporting same.
Sept. 14	do.	3	1	Explosives (fuse and detonators) in drift. Stayed too long. Wet fuse. 2 holes.
Sept. 17	do.	Over 100	1	Explosives (fuse and detonators). Starting raise. Stayed too long. 15 holes.
Nov. 3	do.	do.	1	Skip and shaft timber.
Nov. 19	do.	Less than 5	3	Suffocated, lack of ventilation. Shaft.
Dec. 5	do.	Less than 10	1	Fall of roof in drift.
Dec. 5	do.	Over 50	1	Skip and shaft timber. Underground.
Dec. 28	do.	Over 10	2	Killed by cave caused by blasting (fuse and detonators used). Underground.
		Total	24	

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Of the foregoing accidents it will be observed that six resulting in nine fatalities are directly assigned to explosives and that two fatalities are indirectly attributable to them; the fatal accidents assigned directly to explosives in 1932 caused 37.5 percent of the total fatalities in the metal mines of the State for that year.

It will be further observed that all blasting was done by fuse and detonators, and that two accidents with three fatalities occurred in winzes; three accidents which killed five men and injured three occurred in drifts; and one accident killed one man while he was starting a raise. According to table 1, explosives accidents lead the list of fatalities as to cause in California for the year 1932. And the majority of these accidents, if not all of them, could have been prevented by electric blasting.

A study of the occurrence of mine accidents and their cost in California indicates that there is a clear and vital distinction between the frequency and severity of accidents, and the cost of certain types of injuries; to these types of injuries belong those resulting from accidents caused by blasting or the use of explosives.

There will be no appreciable change in accident rates and the effect that they have on the mounting costs of accidents unless there is a drastic reduction in certain classes of accidents of comparatively low frequency but of marked severity; among these accidents belong those resulting from the use of explosives. Any reduction in the frequency and severity of accidents from explosives can best be brought about by a recognition of unsafe practices and a substitution of safer ones in their places.

In all types of mining, including coal mining, the second important cause of fatalities from mine accidents usually is haulage; in California, however, explosives as a cause of accidents takes second place. It is evident that explosives practice in the mines of California is not conducted in line with the safety standards set by mineral industries of the country as a whole. This is not due to the use of an excessive or unusual amount of explosives. Even in quarries where explosives are important agencies the accidents caused by their use take third place.

In the metal mines[5] of the United States during the 5-year period 1926-1930, the use, or possibly the misuse, of explosives caused 10.97 percent of the fatalities and 1.25 percent of the nonfatal accidents; in the metal mines of California during the same period 12.60 percent of the fatalities and 1.12 percent of the nonfatal accidents were caused by explosives.

Because explosives accidents in California are principally in operations directly or indirectly connected with the breaking of the ground, it is here that changes must be made in current practice if relief is to be obtained. For this reason this report deals primarily with accidents connected with the loading and firing of holes. Fatal accident rates are more dependable as to accuracy than are nonfatal accident rates, particularly where small mines are included; many nonfatal accidents are not reported, but fatalities are brought

5 Adams, William W., Metal-Mine Accidents in the United States: Bull. 362, Bureau of Mines, 1930, 99 pp.

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to attention through various means, including the newspapers in cases of small mine accidents.

SEVERITY AND COST OF EXPLOSIVES ACCIDENTS

One of the outstanding facts connected with explosives accidents is their relatively great severity and resultant high accident cost. Although for the period 1926-1930 explosives accidents accounted for only 1.12 percent of the nonfatal accidents, taking eleventh place as a cause of such accidents, they account for a high proportion of the permanent total and permanent partial disability accidents. An explosives accident is likely to result in fatalities or serious injuries or both, and the number of blasting accidents at some mines indicates lax blasting practice in those properties.

The importance of reducing explosives accidents is particularly emphasized in a study of mine-accident costs. Although this type of accident accounted for nearly 17 percent of the fatalities over a considerable period, the accident cost was only 2.1 percent of the total, on account of the fact that single men predominated among the number killed and compensation is much less for a fatality to a single man than to a married man. The severity of the nonfatal accidents from explosives and blasting is striking; eighteen nonfatal accidents, which are only 1.07 percent of the total, cost $115,205 (compensation and medical), or 19.4 percent of the total cost of all accidents. The cash outlay for industrial insurance alone, however, on account of the insurance cost in these instances, was approximately $194,000.

Permanent partial disability injuries constitute 3.87 percent of the total number of all mining accidents in California and 28.75 percent of the total cost of all such accidents. The same class of injuries from explosives accounts for only 0.42 percent of the total number of mining accidents, but accounts for 12.68 percent of the total cost of all such injuries. This type of injury is of such nature that no malingering can be done. Explosives thus appear to be responsible for approximately 44 percent of the cost of permanent partial disability injuries in mining in California. Electric blasting has played no part in these injuries, so far as the writer is informed, as very little if any blasting has been done by electrical methods. However, "staying too long," "short fuse," "premature blasts," "returned too soon," and "delayed blasts," with "missed shots" form the familiar list of causes, involving the use or possibly the misuse of blasting with fuse and detonators. Out of 169 permanent partial disability accidents in California's mining industry in the period 1927-1930, eye injuries are of frequent occurrence, as they amounted to 41, or nearly 25 percent of the accidents of this class. Many of these injuries resulted from explosives or from flying particles raised by explosives. Of the 41 injuries, 22 were sustained by miners, 4 by muckers, 3 each by laborers and jackhammer men, 2 each by shift bosses and dredgemen, and 1 each by a shaft man, blacksmith, loader, boiler repairman, and carpenter.

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SIZE OF MINE AND PERIOD OF OPERATION

In any accident discussion of California mining experience the size of the mine is a matter of importance. In 1930 California had 476 active operations at which 5,941 men were employed, indicating an average of 12.5 men per operation. A detailed study shows that a mine employing 10 men is a large one in California. In the United States as a whole, statistics indicate that in 1930 only 7.32 percent of the total number of underground man-days were performed at mines employing 1 to 19 men, which, however, constituted 79.2 percent of the operations, whereas in California 22.25 percent of the total number of man-days were performed at mines employing 1 to 19 men, mines of this size constituting 84.3 percent of the operations. Statistics[6] also indicate that for any given class of mines graded according to number of men employed, those which operate continuously generally have better safety records than those that do not, and that larger mines usually have fewer accidents than smaller ones in proportion to the number of men employed. Coordination of effort, an appreciation of a mutual problem, and widespread education, especially insofar as blasting practices are concerned, are essential if accidents in California mines are to be reduced. As part of a movement toward accident reduction, the industry during the past year inaugurated a campaign of first-aid instruction which has resulted in complete or 100 percent training at some 26 mining operations, a total of 1,585 men being trained by the United States Bureau of Mines.

The effect of explosives accidents is most emphatically shown in study of mine accidents in a district involving a large number of small operations. The revival of gold mining in 1929, 1930, 1931, and 1932 has reopened a number of small properties, where in general the explosives practice has been anything but safe or efficient. Investigations of explosives accidents at some comparatively small operations and also at some large ones show that blasting at small operations almost invariably involves the use of fuse and detonators, and with the lack of inspection, supervision, and care usually found in small mining operations, blasting accidents become numerous and are likely to be severe in their effects.

In California during 1930, a total of 390 metal and nonmetallic mines employed 6,243 300-day workers who worked 1,873,148 man-days. Gold mining accounted for 72.57 percent of the operations and 56.08 percent of the man-days; the respective figures for nonmetal mining were 14.86 percent and 21.23 percent, for quicksilver mines 8.73 percent and 7.52 percent, and for copper mines 2.05 percent and 14.55 percent.

There are relatively few large mines in California in comparison with some States. A group tabulation for 1930 shows in general that the average loss of time per accident is lower at the large mines than at the small mines, at which the severity rate particularly is much higher. However, the smaller mines appear to have much fewer nonfatal accidents per 1,000 shifts worked than do the larger mines; hence, the accident-frequency rate of the small mines seems better than that of the larger ones, at least for the year 1930.

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6 Adams, William W., Work cited.

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Because of the closer regulation of blasting in large mines, individual blasting accidents generally occur more often at small mines, particularly those that have been or are being reopened after a shut-down of several months or years. Of 80 fatalities in a group of small mines in California during the years 1894 to 1909, inclusive, 24 were caused by explosives, 20 by falls of rock, 17 by falls of persons, 13 by hoisting, and the other 6 by miscellaneous causes. Of the 24 listed as caused by explosives, loading and firing holes killed 10, missed holes 9, transportation 3, and striking explosives in the muck pile with a hammer, 2. This seems to indicate that the mistakes of 25 years or more in the past are largely of the same type as those which occur today; evidently little progress has been made, at least in some phases of blasting in the metal mines of California.

During the period 1925-1930, according to the Industrial Accident Commission of California, miners suffered 171 fatalities, of which 27 were caused by explosives: explosion, 15; premature blast, 5; overcome by fumes, 3; drilled into missed hole, 2; and 1 each for delayed blast and picking into missed hole.

The following descriptions cover some recent explosives accidents in California's metal mines:

1. On February 13, 1932, 35 shots of a round of 47 shots in a drift of a large California gold mine had been lighted and 12 had not been lighted, but because four men remained too long at the place, three of them were killed and one was seriously injured. Two of them were shovelers who were standing by with carbide lamps for emergency. There had been trouble in spitting the fuses because they had become wet.

Holes were drilled 5 to 6 feet deep. Forty percent gelatin dynamite was fired by No. 6 or 8 detonators, the latter in this case. The fuse was triple-taped, water-safety fuse used for wet ground and for holes under water. Detonators were crimped to the fuse on the surface, 7-foot lengths of fuse being used for drifts. At shooting time it is customary for two men to light the fuses and two to stand by with carbide lamps. Having two men to stand by with lights is usually considered ample precaution to protect shot lighters using carbide lights, but in this case the precaution merely added additional casualties. The evidence showed that the fuse became damp and it was necessary to cut several of them, which caused delay. Electric blasting was adopted following this accident.

2. A similar accident occurred at another large mine in this State on September 17, 1932, whereby one man working in a raise lost his life trying alone to light 22 holes.

3. On April 14, 1932, while two men in a winze in a small California gold mine were loading waste an explosion took place which for some unexplained reason did them no injury. The winze is 5 by 10 feet in section and 24 holes had been fired of which three were reported as misfires. Forty percent gelatin dynamite with triple-tape fuse and No. 6 detonators had been used.

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Following this incident the shots were fired electrically for a time. Shots were connected in series, using delay detonators, and fired by a 50-shot blasting machine; but because of misfires, power blasting in parallel was being considered. On July 30, 1932, two men were sinking a winze and instead of using the electrical method provided, blasted by fuse and detonators. The fuses of two shots were lighted by carbide lights, one of which was extinguished, and after five more shots were lighted, one of the men left. The shots went off and killed one man--a direct result of violation of safety orders and of common sense as well. Such accidents as this are likely to be unknown with electric blasting and are very likely to continue as long as fuse is used.

4. An explosives accident occurred at a small California gold mine on July 24, 1932, resulting in the death of one man and the injury of another. Three holes had been drilled in the face of the drift and three primers had been prepared in three half-sticks of dynamite on the surface; these primers and three sticks of dynamite were placed in a pail which was being carried into the mine at the time of the accident. What caused the dynamite to explode is not known, as there were no witnesses to the accident. The victim's legs were practically blown off below the knees and he was otherwise injured, indicating that possibly the pail of explosives was dropped, the impact causing the dynamite to explode. A box of explosives was stored on the surface and at the time was exposed to the intense heat of the sun; with this type of carelessness in the storing of explosives there is a possibility that undue exposure contributed to the sensitiveness of the explosives.

This accident, as well as others of a more or less similar nature, emphasizes the fact that the method of storage of explosives at some small mines is not conducive to safety, and it is also a good demonstration of the fact that the transportation of primers and explosives together is dangerous practice, although many mining people do not hesitate to carry detonators and explosives together and to minimize or even to deride recommendations against the manifestly dangerous practice.

5. An explosives accident occurred during 1932 at a California gold mine. A man had a contract for sinking a winze at a point about 170 feet from the shaft; four men were employed on the contract or lease, two on each of two shifts. One shift had blasted a round of holes using fuse and detonators; the other shift upon coming to work were informed that six holes had been reported as having missed, but the two men proceeded into the mine, mucked out the rock, and found five missed holes but did not find the sixth.

The superintendent came to the hoist house and upon finding that there were six missed holes, immediately went into the mine and was at the winze at 10 a.m. The contractor asked if he could reblast the missed holes immediately, and the superintendent ordered him not to blast before noon as the smoke would interfere with the workers in an adjacent stope. The superintendent left the winze about 10:30 a.m. and had just reached the shaft station about 170 feet away, when a report was heard. He and the shift boss ran back and assisted in removing the two men, one of whom was dead.

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The holes were in wet ground. Although what is classed as good fuse was being used in this place, one or more misfires were occasionally reported. Following this accident it was decided that all blasting in this winze was to be done electrically; electric exploders had been used formerly by other operators, but their use had been discontinued.

6. On September 14, 1932, a fatal accident caused by explosives occurred at a small California mine. By this accident two men were injured, one fatally. A third man stationed at the portal was not injured.

The writer went to investigate this accident, and was directed to the mine by two small boys. This fact is mentioned for the reason that on arriving at the mine a roll of waterproof, triple-tape fuse and some No. 6 blasting caps were in full view of the portal. There was no one around. It is remarkable that more children are not killed and injured at places where their inquisitiveness is subjected to such temptation. The writer has visited several small mines at which explosives and explosives appliances are allowed to lie around in a way that exhibits extreme carelessness and lack of regulatory measures to prevent serious accidents from indiscriminate use of such materials.

This small mine is a typical one opened in gold-bearing gravel. About 15 feet from the edge of the brush a few three-piece sets hold the ground open. The adit is then driven about 3-1/2 to 4 feet wide and 4-1/2 to 6 feet high for a distance of about 350 feet and is crooked and untimbered. The last 50 feet of the adit was so wet that the flame on a candle could be maintained only with difficulty and fuse would be difficult to light. Two fuses, approximately 3 feet long, found at the portal show that trouble had been previously experienced; the fuse had burned to the detonators but had failed to explode.

In this instance it was plain to see what had happened. Two short holes 2-1/2 to 3 feet long were drilled in the soft, wet gravel and sand formation at the face, which was about 16 feet in cross section; one hole on the left side was standing, but evidence showed that the one on the right had gone off and caused the damage. The two holes were each loaded with one stick of dynamite (strength could not be ascertained) as a primer, using No. 6 detonators and 3 feet of so-called waterproof fuse. It was learned that the injured man was standing about 10 to 15 feet behind the man who was killed. The latter, after lighting the first hole with his carbide light, had much difficulty in trying to light the second because the fuse became wet; as the fuses were only 3 feet long, he had very little time and as has occurred in numerous similar cases he remained too long. This accident undoubtedly would have been prevented had electric blasting been in use.

The mine safety orders of California contain many provisions which, if followed, would eliminate most explosives accidents. A study of accidents in which more than one man has been killed indicates that the safety orders are being disobeyed in many instances.

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At some of the large mines the explosives storage facilities, both surface and underground, are in accordance with the best general practice, whereas at some others there is not even a pretense of safe or sane practice at times. Unquestionably, poor practice in storage of explosives is responsible for many of the accidents in connection with the use of explosives, and especially is poor practice responsible for misfires, premature explosions, and gassing from blasting fumes.

Accidents from transportation of explosives have not been of relative importance, but precautions against them can be much improved, especially at small mines.

Probably no greater opportunity to reduce the more serious types of accidents in California mines is offered than by adopting more approved blasting methods. With the exception of a few instances in sinking shafts and winzes and in driving tunnels, blasting is usually done with fuse and detonators, and by the miners themselves, with some assistance at times from the shift boss.

Experience in California with blasting by fuse and detonators demonstrates that 45 minutes as provided by law permits unsafe interpretations and abuses, and is too short a period before returning to a missed shot. A provision for an 8-hour interval where missed shots are suspected when using fuse and detonators would, if enforced, aid materially in bringing about safer and more efficient blasting. This interval is provided by law in some States, and some States prohibit return to a missed hole until the next day. The interval between blasting and returning to a shot that has failed to fire should be at least 2 or 3 hours under any system involving the use of fuse and detonators, and in fact with any kind of blasting in which the present-day types of explosives are employed.

Of the total number of fatal accidents in California mining for the period 1925-1930, 1.76 percent resulted from suffocation by powder smoke; a major disaster with a loss of 7 lives occurred from this cause in 1917. These accidents are a result of returning too soon after blasting, use of improper explosives which produce gases or of explosives which have been stored improperly blasting of holes which have not been tamped with inert material, or possibly of inadequate ventilation. Although electric blasting will not entirely prevent this type of accident, it will help materially to eliminate fumes from blasting[7] by reducing the poisonous gases from burning fuse and burning explosive, in addition to eliminating other unsafe practices.

Improper charging and overloading not only cause dangerous quantities of poisonous gases and premature shots but also cause delayed shots.

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7 Harrington, D., Data on Metal-Mine Ventilation in 1929: Inf. Circ. 6246, Bureau of Mines, February 1930, p. 7.

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In open-pit work in California where the holes are sprung with dynamite and then blasted with black powder, accidents have occurred from charging the hole too soon after springing when the heat in the bottom of the hole was sufficient to ignite the black powder.

No type of mine accident can be more easily reduced than can blasting accidents by substituting good blasting practice for unsafe practices. If good practice is backed up by intelligent instruction at the face, by effective supervision, and by rigid but just discipline for violations, there is no doubt that considerable suffering can be eliminated and economic advantages gained in California mines.

AN EXAMPLE OF CHANGE IN EXPLOSIVES PRACTICE

Because sections of California[8] have been found to be gassy, including that section in which the tunnels[9] of the Hetch Hetchy water-supply project of the city and county of San Francisco are being driven, blasting practice on that project represents as nearly a maximum degree of safety achievement as is obtainable under existing circumstances.

On account of the nature of the work involved in tunnel driving the use of explosives is one of the major operating items. Unsafe blasting practices offer the greatest hazards in the average tunnel for large groups of the tunnel workmen. Blasting with long rounds in most ground and with short rounds in seamy and blocky ground is common tunneling and ore-mining practice. The use of explosives on the Hetch Hetchy project represents a transition from the former unsafe crowding practices of contracting work when using fuse and detonators, to the more modern and much safer method of using permissible explosives and electric blasting. Probably no better example of what can be accomplished in safe blasting practice is to be found than in the experience of the Hetch Hetchy project.

Between the years 1920 and 1923, four explosions caused by explosives and in which the use of fuse and detonators was involved cost the lives of 11 persons and inflicted injuries on 10 others; these explosions occurred during the driving of approximately 85,000 feet of the Hetch Hetchy tunnel. Following this period, electric blasting was adopted, since when there has been only one explosive accident, involving a loss of one life, caused by tamping an electric primer; an inert primer would have prevented this accident. During the period 1924 to February 1, 1933, 227,080 feet of tunnel has been driven.

There were eight surface magazines at the respective sections on the Coast Range division of the tunnel. These are built to conform to California laws of distances and are of bullet proof construction.

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8 Ash, S. R., and Rankin, J. H., Permissible Electric Cap Lamps and Ventilation in Certain California Mines and Water-Tunnel Construction: Bull. 359, Bureau of Mines, 1932, pp. 2-4.

9 Harrington, D., Progress of Metal-Mine Ventilation in 1930: Inf. Circ. 6469, Bureau of Mines, 1931, pp. 5-12.

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The explosives are taken into the tunnels by the motorman. Two-compartment, insulated powder cars (permitted by law, but unquestionably not the safest practice) are provided for the explosives and detonators, which are kept separate. The transportation of primers is always attendant with some danger.

Not more than 100 pounds of explosive is stored underground. It is kept in locked wooden boxes. This explosive is sufficient for single-shot plugging only, which is done with permissible explosive and permissible single-shot blasting units. Explosive sufficient for the entire round up to 40 holes is brought into a tunnel from the surface.

Explosives of the Gelatin-Colites and Herco-Gels have been used since 1930; electric detonators of No. 8 strength and delay types are used. Explosives and detonators are not handled by the same man at the same time. The miners and shift boss load the holes. Cartridges are used and care is taken to guard against air-spacing. The cartridges are slit and the explosive is carefully rammed. Clay stemming is used and a wooden-type bar is used in tamping. The primer is placed as the second stick in the bottom of the hole.

Rounds of 20 to 40 holes are drilled with compressed-air drills using water. Four to seven sticks of 1-1/8- by 8-inch permissible explosive are used per hole and from 5 to 9 feet are "pulled," depending on the ground.

Shooting is done by a fire boss who has satisfied the Industrial Accident Commission as to his eligibility to detect gas and to take precautions against gas ignitions; one fire boss is employed on each shift. One to 40 shots are fired at one time, with delay-action exploders.

Power blasting in parallel (440 volts a.c.) is used for the main rounds, a special blasting switch[10] controlling a momentary circuit of very short duration being used for this purpose. The locked switch is operated by the fire boss from the shaft crosscuts after all men have retreated about 5,000 feet or more from the face.

Misfires were common prior to the adoption of electric blasting, and are assigned as the cause of all previous explosives accidents, costing 11 lives. No fatalities have been caused by misfires since adopting electric blasting. Two nonfatal accidents occurred when old unexploded primers used for plugging, and carelessly not reported, were struck in picking for posts. Inert primers,[11] it is believed, would prevent this type of accident; and single-shot blasting for plug shots and parallel blasting with a power circuit have eliminated misfires.

An examination is carefully made after blasting to try to detect any misfires which may have occurred. In case of known or suspected misfires which are examined and reported, a new primer is used and the hole fired after the

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10 See footnote 8.

11 Manning, R. I. C., and Soule, Thomas, Electrical Blasting at the Morenci Mines of the Phelps Dodge Corporation, Morenci, Arizona; The Explosives Eng., vol. 9, June and July, 1931, pp. 209-212, 250-254.

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stemming has been removed by water jet. The legs of all electric detonators are short-circuited and the short is removed following a check on the main line. It is impossible to close the circuit unknowingly, and opening the line switches shorts the blasting line at the outby point. No record of misfires is available; however, they are rare and appear to be a result of series blasting for plug shots when more than one shot was fired from a high-voltage power circuit.

The number of explosives accidents not involving a loss of life in the tunneling operations of the entire State is not known. The use of the inert primer in tunneling operations would aid materially in preventing explosives accidents from missed shots, loading holes, striking primers, removing charges, and transportation, and would be a safeguard in various hazardous conditions in tunneling and metal-mine operations. Such a primer appears to offer a feasible remedy for certain types of explosives accidents, whether they involve the use of fuse and detonators or of electric exploders.

SUMMARY OF EXPLOSIVES ACCIDENTS IN CALIFORNIA INDUSTRIES

The use of explosives has cost many lives and resulted in serious injuries in the mining, quarrying, and construction industries in California. A study of the explosives accidents in construction work indicates that for the same number of shots fired, accidents occur most frequently in tunneling operations, especially when fuse and detonators are used. The Industrial Accident Commission has a record of 133 explosives accidents resulting in a loss of life and serious injuries, 94 persons being killed and 46 injured. Table 2 shows some of the various factors involved in the 133 accidents, but does not include all accidents whereby no one was killed and only injuries resulted, or of other accidents not directly involved in direct blasting operations. In the California mining industry, for the period 1924-1930, there were 30 fatalities and 129 injuries (potential fatalities) from explosives from all causes. The blasting system in these instances was one involving the use of fuse and detonators. Until recently there has been no appreciable amount of electric blasting in Californian mines, although now it has been generally adopted in the larger and more important tunneling operations; but fuse and detonators continue to be used in smaller tunneling jobs.

Whether accidents would probably have been prevented if electric blasting methods had been used instead of fuse and detonators is debatable to some extent, but there are accidents classed as caused by premature explosions; missed shots; short, fast, wet, and delayed fuse; crimping caps; spitting too many; staying too long; returned too soon; counted too many shots; besides others, that unquestionably would not have happened if electric blasting had been employed.

Certain types of explosives accidents cannot be prevented under certain practices (in long rounds, shafts, winzes, long raises) unless electric blasting is used. The data given in table 2 represent the combined opinion of the Safety Department of the State Industrial Accident Commission and that of the writer.

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Table 2. - Summary of typical explosives accidents in Californian industries

Accidents		133
Persons killed	94	
Persons injured	46	
Total killed and injured		140
Accidents:		
At mines	59	
At quarries	10	
On construction (tunnels principally)	51	
Miscellaneous	13	133
Accidents using fuse		130
Accidents using electric blasting		1/ 3
Injured and killed according to cause:		
Premature blasts	11	
Stayed too long	27	
Drilled or picked into missed hole	57	
Other causes (tamped too hard, short fuse, detonators, returned too soon)	33	
Cause unknown	12	140
Accidents that probably would have been less in frequency if electric blasting had been used		114

1/ Two at tunneling operations. One caused by tamping primer and the other by stray current.

GENERAL DISCUSSION

Mine Safety Orders 1743 to 1745, inclusive, pertain to explosives practice in California mines. The noncompliance, whether intentional or unintentional, with certain sections of these orders is in evidence almost every time an accident occurs. Obviously, repeated and uneventful violation of safety rules is conducive to a tolerant attitude toward unsafe practice; however, unsafe practice will sooner or later result disastrously. Three pertinent sections are part of Safety Order 1745, namely:

> The number of explosions in every blast, except in cases of simultaneous firing, shall be counted by the man firing the same, and if the total number of explosions is less than the number of charges fired, a report of the discrepancy shall be made as the

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superintendent shall direct. When a blast has been fired and it is not certain that all the charges have exploded, no person shall enter the place where such charges were placed within forty-five minutes after the explosion.

(g) No man shall "spit" more than fifteen fuses at one time and should it be necessary to blast a greater number of holes than fifteen, he must have assistance.

(k) Electric exploders only shall be used in shaft sinkings, except when such use is not feasible.

Every one of these orders repeatedly has been found to be deplorably deficient. Experience would appear to indicate that they are based on average results rather than minimum requirements, and the wording of an order sometimes permits of a construction that inevitably leads to accidents. Fifteen fuses appear to be entirely too many for any one man to ignite, when alone, except under most favorable conditions. Experiences cited in this report confirm the fact that under some conditions even two shots are too many when using fuse and detonator. The exception in section (k) just quoted nullifies this section to the extent that it is almost universally evaded, as this report shows in part by examples of explosives accidents. If there is one type of accident the avoidance of which calls for a close interpretation and compliance with rigid orders, it is that relating to explosives practice, and the industry eventually pays the bills for errors of practice in human wreckage and economic distress.

Following the Mitchell shaft disaster of 1930 at the Hetch Hetchy water-supply project where 12 men were killed—coming as it did almost immediately after the Alameda Creek tunnel disaster (7 lives lost), and the Glenn mine fire when 5 lives were lost—a committee[12] was appointed by the former Governor of California, This committee, among other things, recommended that in California mines—

p. Where at all feasible, electrical blasting should supersede the prevailing use of fuse and detached "caps" or detonators. However, electrical blasting is by no means foolproof and there are definite hazards with delay action detonators, particularly where explosive gas may be found. Electric detonators should have the leg or leading wires short circuited on the surface before being sent underground, and this "short" should be maintained until practically ready to shoot. All blasting in sinking shafts, dip slopes, and winzes should be by electricity.

q. Explosives or detonators should not be stored at any point where an explosion would do damage to the exit for men, nor should they be left temporarily within 200 feet of any shaft station.

12 See footnote 8.

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If there are to be any changes in current practice, the remedy is going to come in large part, if not completely, from the mining industry itself. Probably no activity in mine safety practice has a wider distribution of informative literature than that pertaining to explosives and their use; every carton, every box, and every utility is accompanied with its usual admonishments and list of "don'ts." The solution of the problem of accidents from explosives is to adopt what is known to be safe and efficient practice.

Most of the accidents that occur with explosives can be prevented. The safest methods today of handling and using explosives cannot necessarily and unalterably be the method of tomorrow, and their discussion is beyond the scope of this report. Among the many important services given by explosives manufacturers to users of explosives is the sending of their technically trained men into the field to show users the safest and most efficient methods. This same procedure would, if followed by the safety departments of the State and the insurance carriers, be very effective. The work should consist of education in safer practices for all methods of blasting, and be of such a nature as to be within the grasp of the workmen. The explosives companies, especially the group known as the Institute of Makers of Explosives, the State safety department, the National Safety Council, and the United States Bureau of Mines, all issue bulletins describing safe and dangerous practices; what appears to be lacking is a definite and effective educational system at our mines.

An unbiased review of this literature will reveal the fact that electric blasting methods are safer than methods using fuse and detonators.

Some of the common reasons for not using electric blasting that are advanced by ore miners, partly justifiable only because of its being an innovation, are as follows:

1. Electric blasting is not believed to be feasible in stopes and in general ore-mining practice.

2. There are no examples of such practices in metal mines.

3. The copper wires will interfere with gold recovery in milling practice (California).

4. There is a lack of knowledge of safe methods, and no one with experience to instruct in the use of electric blasting methods.

5. Comparisons are not indicative in metal mines because the number of holes blasted under each system is not known.

6. Prejudice exists against electric caps based on a lack of familiarity with their use.

7. A fear exists that they are dangerous to handle.

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8. A belief prevails that an electric detonator would cost more than the combination of fuse and cap.

9. Electric blasting involves a costly system of wiring and complicated electric devices.

10. Fuse blasting is simpler for the individual miner.

11. Fuse blasting is safer than poorly installed electrical blasting systems.

12. Electric blasting is not believed to be feasible for bulldozing.

Explosives Records in Anthracite Mining Applicable to Ore Mining

There are no published studies of any importance on ore-mining practice which compare blasting by fuse and detonators with electrical blasting methods. However, a study has been made of the Pennsylvania anthracite blasting practice, by S. P. Howell[13] of the United States Bureau of Mines, which is a valuable experience record for any one interested in explosives accidents and their prevention. The accidents discussed and the conditions under which they occurred have many counterparts in the ore-mining field. This is particularly evident when it is realized that anthracite is hard, blasting is predominantly off the solid in the sense that cutting or shearing is infrequently done, and considerable rock work is done for mining purposes; in fact, anthracite mining has numerous features and hazards analogous to those encountered in metal mining, even the fact that anthracite dust is not explosive. For this reason much more explosive is used per unit of anthracite production than of bituminous coal produced.

Howell enumerates explosives accidents under 17 different classes and details circumstances accompanying 299 fatal and 386 nonfatal accidents involving an estimated firing of 161,265,750 shots, of which 4.4 percent were fired with squibs, 53.5 percent with fuse, and 42.1 percent with electricity. It was found that the greater number of accidents involving explosives were caused by premature shots. In the order of their frequency as to the method of firing used, it was found that when using squibs the rate was 12.2 accidents per million shots, 2.7 accidents per million fuse shots, and 1.9 accidents per million electrically fired shots. Howell says, "Unquestionably, electrical firing of shots is by far the safest method."

In reference to practice in the western metal-mining field, Manning and Soule[14] described a successful electrical blasting system at the Morenci mine

13 Howell, S. P., Explosives Accidents in the Anthracite Mines of Pennsylvania, 1923-1927: Bull. 326, Bureau of Mines, 1931, 93 pp.

14 Soule, Thomas, and Williams, W. J., How Can Blasting Accidents Be Eliminated?: Address before the California Safety Society, June, 1932.
Soule, Thomas, Blasting with the Inert Primer: Address before the California Safety Society, July, 1932.

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of the Phelps Dodge Corporation, Morenci, Ariz. particularly mentioning the use of the inert primer. It is recognized that a careful analysis of actual blasting accidents is of extreme value. Such an analysis[15] has been made of the Morenci operation noting misfires in particular. A careful investigation was made of the results of shooting a total of more than 329,500 shots electrically with inert primers; no misfires could be traced to the use of 152,700 instantaneous electric detonators. The remaining 176,800 detonators were of delay electric types, and of this number there was not a misfire that could be traced to the inert primer where the holes were charged properly.

Electric blasting systems are by no means free from hazards, and unless properly understood, installed, and operated, they can be dangerous. Electric blasting is now required by all companies in Arizona metal mines for long raises and shaft work. It is required in Ontario in all shafts and steep raises. One large Arizona mine uses it exclusively for all classes of work, and others are seriously considering its adoption. The average miner, regardless of nationality, can be taught to blast electrically in a safe and efficient manner, and there is absolutely no good reason why California's mines should not use electrical blasting throughout and be made far safer than they now are.

ACKNOWLEDGMENTS

This report is made possible by the cooperation of the State Compensation Insurance Fund organization and the Safety Department of the Industrial Accident Commission of the State of California. Special acknowledgment is made to C. H. Fry, superintendent of safety, and F. L. Lowell, chief mining engineer, of the Safety Department of the Industrial Accident Commission, to Frank J. Creede, manager, and J. J. Gallagher, secretary, of the State Compensation Insurance Fund, and to the various explosives manufacturers whose data have been drawn upon.

15 See references in footnote 14.

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